Review Article

Nanorobotics: A Small World with Big Promises

Dr. Amol Badgire[1], Dr. Vaishnavi Kherde[2], Dr. Ramchandra Kabir[3], Dr.Praveen Dhore[4], Dr.Ajit Shinde[5]

[1]Hod And Professor, Department Of Conservative Dentistry And Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur.
[2]Post Graduate Student, Department Of Conservative Dentistry And Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur
[3]Professor, Department Of Conservative Dentistry and Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur.
[4]Reader, Department Of Conservative Dentistry and Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur.
[5]Reader, Department Of Conservative Dentistry and Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur.

Abstract:

In the era of artificial intelligence, dentistry has undergone significant transformation for the benefit of mankind by transforming to nano dentistry. A several nanostructure such as, nanorobots, nano fibers, nano rods, nano spheres has been reviewed for various dental applications. The successful element of nanotechnology, known as nanorobotics, focuses on creating and constructing nanorobots, ranging from 0.1 to 10 nm made up of molecular or nanoscale components. Potential applications of nanorobotics in endodontic treatment include nanoparticles in local anaesthesia, vaccine administration, antibiotics, dentition renaturalization, bone replacement therapy, nanocomposites, permanent cure for hypersensitivity, covalently bonded diamond like enamel and dentifrobots for continuous oral health care. The future promises an era of dentistry where every procedure is carried out using equipment and devices powered by nanotechnology. Through the use of nanotechnology, genetic and tissue engineering, it is possible to recreate even the hardest tissue of body i.e enamel. The main objective of the poster is to emphasize the applications, challenges, and future advancements of nanotechnology in the field of endodontics.

Keywords- Nano robots, Nano dentistry, Nanotechnology

Corresponding Author: Dr. Amol Badgire, 1Hod And Professor, Department Of Conservative Dentistry And Endodontics, Midsr Dental College, Vishwanathpuram, Ambajogai Road, Latur

INTRODUCTION:

Researchers predict that advanced and effective management at the microscopic level, referred to as nanotechnology, will be pivotal in the future of periodontal and dental health. (1,6). One of the main objectives of dentistry is to maintain oral health, which can be assessed at the levels of prevention, diagnosis, and treatment. A physician can also avoid major difficulties brought on by a delayed diagnosis by making an accurate and timely diagnosis. In nanotechnology, 2– 5 matter is manipulated atom by atom. Nanotechnology is the field that studies incredibly tiny structuresThe term "Nanotechnology" was introduced by Prof. K. Eric Drexler. The prefix "nano" comes from the Greek word meaning "dwarf," and it refers to something extremely small or miniature in size (2,5). Nanotechnology applications in supramolecular chemistry, including self-assembling drug carriers and gene delivery systems, have made remarkable progress. Recent advancements in dental diagnostics, materials, and treatments include the use of nanoparticles, nanocapsules, polymer-protein and antibody conjugates, polymer-drug conjugates, antibody technologies, nano-precipitation, nanocrystals, in situ polymerization, liposome technology, emulsification techniques, tissue engineering and repair, dendrimer technologies, and molecular imprinting (3). The growing interest in the potential applications of nanotechnology in dentistry is leading to the emergence of a new field called nanodentistry. In dentistry, new treatment options include covalently bonded diamondized enamel, dentition renaturalization, permanent cure for hypersensitivity, full orthodontic realignment in a single office visit, local anesthesia, and continuous oral health care with the help of mechanical dentifrobots that eliminate cavity-causing bacteria and even repair tooth imperfections where decay has started (4). Dental nanorobots may utilize specific motility mechanisms to navigate human tissue with precision, collect energy, and sense and manage their surroundings in real- time.(1) The aim of this article is to evaluate the current state of nanotechnology in dentistry and provide some predictions for the future while emphasizing the moral and safety concerns surrounding its application.

What are Nanorobots?

Nanorobots are theoretical microscopic devices that operate on the nanometer scale (1 nm equals one millionth of a millimeter). Once developed beyond the hypothetical stage, these robots would function at the atomic, molecular, and cellular levels to carry out tasks in both medical and industrial sectors, transforming what was once considered science fiction into reality. These devices are computer-controlled robots built with nanometer-scale components, crafted with molecular precision, and are typically minuscule in size.(5)

Components of nanorobot:

- 100nm manipulating arms,
- 10 nm sorting rotors for purification on a molecular scale.
- Smooth, ultra-hard surfaces composed of atomically perfect diamond

Fig. 1 Dental nanorobot
(Courtesy-Davinci institute-www.impactlab.com)

MECHANISM OF ACTION

Nanorobots can derive power by metabolizing local glucose, oxygen, and externally provided acoustic energy, as well as other possible energy sources within the body. These devices are equipped with onboard computers that can execute more than 1,000 calculations per second. Communication with nanorobots is facilitated via broadcast-type acoustic signals. A navigation system within body ensures precise positioning of the nanorobots and tracks their locations. The nanorobots are capable of distinguishing between different cell types by identifying surface antigens, employing specialized chemotactic sensors designed to target specific antigens on cells. After accomplishing their task, these nanorobots can be naturally excreted through the body’s waste elimination systems or extracted using active scavenger mechanisms. (17,18)

Application of Nanotechnology in Dentistry

Local Anaesthesia

For the effective use of local anaesthesia, a colloidal suspension containing millions of microscale robots is applied to the patient's gingiva. Nanobots which come into contact with the mucosa or crown surface gain assess to the pulp through the lamina propria, gum crevice or dental tubules. As it reaches pulp, it blocks whole sensation by regulating the nerve impulses in the affected tooth. After the treatment is completed, it restores sensation, ensuring a comfortable, painless and needle-free experience for the patient, free from anxiety. The anesthesia works quickly, is reversible, and comes with no side effects or complications. (1,7,10)

Dental Caries

Dental caries, trauma, and tooth abnormalities can result in dental pulp infections, which, if left untreated, can develop into pulpitis, pulp necrosis, and ultimately apical periodontitis. In these situations, root canal treatment (RCT) is advised, as it removes the infected pulp tissue and bacteria from the entire root canal system, facilitating the healing of periapical conditions. For successful endodontic treatment, proper biomechanical preparation, irrigation, obturation is necessary. Ultrasonic or laser pulses are used to generate shockwaves in the fluid, enhancing the removal of pathogens and tissue debris, thereby improving the effectiveness of root canal therapy. The energy from these pulses rapidly dissipates, limiting their travel to about 900 micrometers. Currently, existing nanobots that can be injected into teeth to target pathogens are especially useful in root canal procedures. These nanobots have a helical design and are composed of silicon dioxide, with iron incorporated into the silica structure to provide magnetic properties. The nanobots can extend up to 2,000 micrometers and generate heat, employing a hyperthermia-based method to potentially eliminate nearby pathogens. These nanobots were exposed to rotating magnetic fields to assist in their removal and reduce the chances of nanoparticle accumulation and toxicity. Consequently, the hyperthermia-based bactericidal approach provides a safer option compared to chemical treatments and antibiotics.(8)

Dental Hypersensitivity

Hypersensitivity occurs due to changes in pressure that are hydrodynamically delivered to the pulp. In hypersensitive teeth, the dentinal tubules are twice as wide and possess eight times the surface density compared to those found in non-sensitive teeth. Gingival recession can result in cementum loss, which may contribute to moderate to severe dentin hypersensitivity. (1). Upon reaching the dentin, the nanorobots enter dentinal tubules, which range from 1 to 4 μm in diameter, and progress toward the pulp. Their movement is directed by a blend of chemical gradients, temperature variations, and navigational cues, all coordinated by the onboard nanocomputer under the dentist's guidance.(17) These reconstructive dental nanorobot selectively and accurately block the dentinal tubules within minutes, providing the patient with a fast and permanent solution to hypersensitivity.This procedure can also be utilized for anesthesia and managing patient anxiety (1,10).

Nanosolution

Due to their ability to produce unique and dispersible nanoparticles, nanosolutions can serve as effective bonding agents. Homogeneity is guaranteed, as the adhesive is consistently mixed to perfection. Furthermore, nanoparticles are used as sterilizing agents in the form of nanoscale emulsified oil droplets, designed to target and remove pathogens.(1,12).

NANOCOMPOSITE

Microfillers in composite materials and microcore substances have been utilized for quite some time. Although the size of filler particles cannot be reduced below 100 nm, nanocomposite particles are sufficiently small to be engineered at the molecular level. These nanoparticles improve the compressive strength of the material. Filler particles at submicron sizes, like zirconium dioxide, play a key role in enhancing polishability and overall aesthetics. Using particles of this size can increase the material's vulnerability to brittleness, cracking, or fracturing after curing. To overcome this, hybrid composites and those with a wider range of filler particle sizes have been developed, providing a more balanced combination of strength and aesthetics. However, issues like nanoparticle clumping or agglomeration can still compromise the material. This can be mitigated by employing a specialized coating technique during particle production, which eliminates weak areas and maintains uniform strength throughout the core. Furthermore, the even distribution of nanoparticles results in a smoother, creamier texture that enhances flowability. Once cured, these characteristics contribute to the material's dentin-like cutability and polishability. (1,10)

Bone Replacement Material
Bone is a naturally occurring nanostructure that is reinforced by inorganic components and mostly consists of organic molecules like collagen. In the domains of dentistry and orthopedics, nanotechnology seeks to replicate this natural structure, particularly in the production of nanobone. The architecture of nanocrystals in this context is loosely structured, with nanopores separating them. Silica molecules are added to these pores' surfaces to change their ability to adsorb proteins. These hydroxyapatite nanoparticles can be used to treat bone defects effectively(1,10).

Nanodentrifices (Dentifrobots)
A nanorobotic dentifrice, residing below the occlusal surface and delivered through mouthwash or toothpaste, could patrol both supra-gingival and subgingival areas once a day. It would break down trapped organic matter into harmless, odorless vapors while consistently removing calculus. Properly designed dentifbots could detect and eliminate harmful bacteria found in plaque and other areas, helping to prevent halitosis. These tiny mechanical devices, moving at speeds of 1 to 10 microns per second, would be cost-effective and programmed to deactivate if accidentally swallowed.(17)

Major Tooth Repair/ Nanotissue Engineering
Complete tooth replacement involves replacing the entire tooth, encompassing both its cellular and mineral components. This procedure is enabled through the integration of nanotechnology, genetic engineering, and tissue engineering. Chen et al. utilized cutting-edge nanotechnology advancements to replicate the natural biomineralization process, successfully creating dental enamel, the hardest tissue in the human body. They accomplished this by employing well- organized microarchitectural units of nanorod-like calcium hydroxyapatite crystals, aligned in parallel (17).

Impression Materials
Nanofillers are integrated into vinylpolysiloxanes, offering a distinctive enhancement to siloxane impression materials. This formulation improves flow, enhances hydrophilic properties, and provides greater detail accuracy. The integration of nanofillers in vinyl siloxanes results in an impression material with improved flow, enhanced hydrophilic properties, reduced voids at the margins, better model pouring, and increased precision in detail.(3)

Advantages
- Increased fluidity
- High tear resistance
- Enhanced hydrophilic properties
- Resistance to distortion and heat
- Snap set, which reduces errors caused by micro-movement

Orthodontic Treatment
As a tooth moves along an archwire, frictional forces create resistance to its movement. Excessive orthodontic forces can lead to complications such as anchorage loss and root resorption. Katz's research revealed that because of their superior dry lubricating properties, inorganic fullerene-like tungsten disulfide nanoparticles (IFeWS2) can be used to coat orthodontic wires to reduce friction. In the future, orthodontic nanorobots could directly interact with periodontal tissues, enabling rapid, painless tooth movement, such as straightening, rotating, and vertical repositioning, within a matter of minutes to hours.(1,5)

Dental Implants
The topography and surface contact area are essential for a successful osseointegration process. Nonetheless, bone adhesion and stability are also crucial. Nanotechnology can significantly accelerate bone growth and improve predictability with implants. By adding nanoscale layers of

hydroxyapatite and calcium phosphate, the implant surface becomes more complex, promoting osteoblast formation. Extensive research into optimizing microtopography and surface chemistry has led to significant advancements in material engineering. These advanced implants offer enhanced biocompatibility by featuring nanocoatings that mimic biological materials, promoting better tissue integration(1,11).

Challenges faced in the field of nanodentistry

Engineering challenges

- The practicality of mass production methods.
- Ensuring accurate placement and assembly of molecular-scale components.
- Coordinating and controlling the operations of numerous independent microscale robots at the same time.

Biological Challenges

- Creating biocompatible nanomaterials.
- Ensuring alignment with the intricate structures of the human body.

Social Challenges

- Ethical considerations.
- Gaining public acceptance.
- Ensuring regulation and human safety. (3,10)

CONCLUSION

Nanotechnology is still in its infancy, and its full integration into dental and clinical practices remains a distant goal. Nevertheless, there is little doubt that progress in nanomaterials will enhance the dental experience, as well as pave the way for the creation of advanced diagnostic tools and potentially groundbreaking treatments and cures. Looking ahead, nanotechnology is anticipated to emerge as a highly effective alternative to current dental practices. However, achieving this will require overcoming the present challenges of the technology through effective collaboration and a thorough understanding of how to apply nanotechnology in practice.

REFERENCES

1. Shetty NJ, Swati P, David K. Nanorobots: Future in dentistry. The Saudi dental journal. 2013 Apr 1;25(2):49-52.
2. Sagar S, Shashank, PahujaRK, DhaliwalA, KaushalS. Nanotechnology – Innovation and New Patronage in Dentistry. J Periodontal Med Clin Pract 2016;03: 112-12
3. Chandki R, Kala M, Kumar KN, Brigit B, Banthia P, Banthia R. 'Nanodentistry': exploring the beauty of miniature. Journal of Clinical and Experimental Dentistry. 2012 Apr;4(2):e119.
4.
5. Aeran H, Kumar V, Uniyal S, Tanwer P. Nanodentistry: Is just a fiction or future. Journal of Oral Biology and Craniofacial Research. 2015 Sep 1;5(3):207-11.
6. Bumb SS, Bhaskar DJ, Punia H. Nanorobots and challenges faced by nanodentistry. Guident. 2013 Sep 1;6(10):67-9.
7. Freitas Jr, R.A., 2005. What is nanomedicine? Nanomed. Nanotech. Biol. Med. 1, 2–9.
8. Freitas, R.A., 2000. Nanodent. J. Am. Dent. Assoc. 131 (3), 1559–1566
9. Bathla S, Hans MK, Dutta SK, Bhattacharyya S, Talukdar A, Saifi S. Nanobots: An endodontist saviour. Bioinformation. 2024 Aug 31;20(8):898.
10. Raval C, Vyas K, Gandhi U, Patel B, Patel P. Nanotechnology in dentistry: A review. Journal of Advanced Medical and Dental Sciences Research. 2016 May 1;4(3):51.
11. Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res. 2006; 17:62–69. doi: 10.4103/0970-9290.29890
12. Albrektsson, T., Sennerby, L., Wennerberg, A., 2008. State of the art of oral implants. Periodontology 47, 15–26.
13. Nagpal, Archana, Kaur, Jasjit, Sharma, Shuchita, Bansal, Aarti, Sachdev, Priyanka, 2011. Nanotechnology– the era of molecular dentistry. Indian J. Dent. Sci. 3 (5).
14. Lampton, C., 1995. Nanotechnology promises to revolutionize the diagnosis and treatment of diseases. Genet. Eng. News 15, 23–25
15. Abhilash, M., 2010. Nanorobots. Int. J. Pharma Bio. Sci. 1 (1), 1–10.

16. Addy M, West N. Etiology, mechanisms, and management of den tine hypersensitivity. Curr Periodontol. 1994;2:71-7.
17. Sahoo SK, Parveen S, Panda JJ.The present and future of nanote chnology in human health care. Nanomedicine: Nanotechnology, Biology, and Medicine. 2007;3:20-31.
18. Dalai DR, Gupta D, Bhaskar DJ, Singh N, Jain A, Jain A, Singh H, Kadtane S. Nanorobot: a revolutionary tool in dentistry for next generation. Journal of Contemporary Dentistry. 2014 May 1;4(2):106.
19. Babel S, Mathur S. Nanorobotics—Headway towards dentistry. Int J Res Sci Technol. 2011;1(3):1-9.